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An Adaptive Cognitive Temporal-Causal Network Model of a Mindfulness Therapy Based on Humor

S. Sahand Mohammadi Ziabari and Jan Treur

Abstract In this paper the effect of a humor therapy is modeled based on a Network-Oriented Modeling approach. Humor therapy is a mindfulness therapy which has been used since many years ago, when Abu Bakr Muhammad ibn Zakariya al-Razi (https://en.wikipedia.org/wiki/Muhammad_ibn_Zakariya_al-Razi) as a Persian scientist who used humor theory to distinguish one contagious disease from another, to make stressed individuals more relaxed. The presented adaptive temporal-causal network model addresses the computational modeling of humor therapy for a person who in the first step triggers two incongruent beliefs in order to get the humor from a humor context to overcome an ongoing stressful event. This happens by showing a comedy movie. As a result, the stress level in the body reduces. Hebbian learning is incorporated to strengthen the effect of the humor therapy.

Keywords Cognitive temporal-causal network model · Hebbian learning · Extreme emotion · Humor therapy · Mindfulness

1 Introduction

To handle stress and its consequences for mental and physical health, often mindfulness therapies [8, 9] are considered. A wide variety of such therapies [33] working according to different mechanisms, is available, some of which have been analyzed by computational modeling; for example, see [30, 18–20]. The current paper addresses humor therapy. In the Oxford English Dictionary [26], humor is defined as 'That quality of action, speech, or writing which excites amusement; oddity, jocularity, facetiousness, comicality, fun'. Examples of contexts of humor are funny films, audio and videotapes of humorous songs, or reading materials [17]. Humor is considered when a driver like a comedy movie, triggers mental action involving cognitive and

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affective mental states, and often responses like mirth and laughter, which is the most common conducting expression of a jocular experience [12].

As has been described in [23], humor has psychological, social, emotional, behavioral, and cognitive components. Graceful emotional feeling are usually the result of humor and laughter [25]. Humor therapy has been considered as one of the distraction techniques, one of the remarkable uses of cognitive-behavioral techniques, in pain management and control [1, 14]. In [29] it has been noted that:

> In light of the light prevalence of chronic pain and its impact on physical and psychological perspectives among older people, the use of humor therapy as a means of reducing pain and loneliness as well as increasing happiness and life satisfaction is very appealing. [29], p. 3

Several minutes of powerful laughter generate results similar to exercising on a rowing machine or bicycle for about 10–15 min [5]. The reason is just because of releasing endorphins after an intensive laugh. In [10] the meaning of humor is defined.

The paper is organized as follows. In Sect. 2 the neuropsychological principles of the effects of stress and the parts of the brain which deal with stress are addressed, and the mechanisms by which humor can affect this. In Sect. 3 the adaptive temporal-causal network model is introduced. In Sect. 4 the simulation results of the model are discussed. Finally, Sect. 5 is a discussion Conclusion.

2 Neuropsychological Principles

In [12, 34] it has been illustrated that humor and laughter make lung capacity increase, abdominal muscles strengthen and also immunoglobulin A increment, the antibody which is generated by our immune system. Also, as it is declared in [1, 28] natural killer activity such as immunoglobulin G immunoglobulin M levels increases for 12 h since laughter or other humorous encounters and as stated in [1] the results of humor are also reduction in cortisol, increase in hormones and epinephrine and these changes are beneficial to the person's health. The continuous use of humor results in betterment in pain thresholds [13]. As stated in [3] the left amygdala is responsible for conscious and cognitively controlled emotional actions and the right amygdala is involved in unconscious and automatic emotional actions. Therefore in [21] it has been found that left amygdala activation will return the tendency of humor.

Pathways between Amygdala and other brain parts has been discovered: Amygdala and orbitofrontal cortex for discrimination of the valence, amygdala and cingulate cortex for computing an object's biological value, amygdala and anterior insula for emotional feelings, and amygdala and (colliculus and pulvinar) for filtering out a distractor driver [22]. Release of endorphins in the brain assists to control the pain as has been described in [7, 35]. In [4] it has been claimed that managing the pain accompanied with humor is more effective than managing the pain on itself. Also, in treatment of patients qualitative research described in [2, 9] supports the impacts of humor. As has been mentioned in [21] there are eight psychological benefits of humor based upon available quantitative and qualitive evidence in literatures discussed in [2]:

> 1. Humor reduces anxiety. 2. Humor reduces tension. 3. Humor reduces stress. 4. Humor reduces depression. 5. Humor reduces loneliness. 6. Humor improves self-esteem. 7. Humor restores hope and energy. 8. Humor provides a sense of empowerment and control. [2]

As mentioned in [5, 6] there are seven particular physiological gains that consists of central nervous, muscular, respiratory, circulatory, endocrine, immune, and cardiovascular systems. In much literature it has been claimed that there is a dual way architecture between sensory information and amygdala [15, 22].

In [27] it has been found that a positive emotional driver like pleasant taste or happy faces and a negative driver such as tremulous faces, sad faces or angry faces will activate the amygdala. There are differences in the experience of humor in relation to individual differences in personality, character strengths, age, gender, language, and culture. Research described in [10] has considered functional aspects of humor, such as its role in creativity, emotion regulation, and group cohesion. In [24] the incongruity and control state between them.

3 The Adaptive Temporal-Causal Network Model

First the Network-Oriented Modelling approach used to model this process is briefly explained. As discussed in detail in [31, Chap. 2, 29] this approach is based on temporal-causal network models which can be represented at two levels: by a conceptual representation and by a numerical representation. These three notions form the defining part of a conceptual representation of a temporal-causal network model:

- **Strength of a connection $\boldsymbol{\omega}_{X,Y}$** Each connection from a state X to a state Y has a *connection weight value* $\boldsymbol{\omega}_{X,Y}$ representing the strength of the connection, often between 0 and 1, but sometimes also below 0 (negative effect) or above 1.
- **Combining multiple impacts on a state $\mathbf{c}_Y(..)$** For each state (a reference to) a *combination function* $\mathbf{c}_Y(..)$ is chosen to combine the causal impacts of other states on state Y.
- **Speed of change of a state $\boldsymbol{\eta}_Y$** For each state Y a *speed factor* $\boldsymbol{\eta}_Y$ is used to represent how fast a state is changing upon causal impact.

In Fig. 1 the conceptual representation of the temporal-causal network model is depicted. A brief explanation of the states used is shown in Table 1 (Table 2).

Next, the elements of the conceptual representation shown in Fig. 1 are explained in some more detail.

The described conceptual representation defines a numerical representation of the network model as follows [35, Ch 2]:

- at each time point t each state Y in the model has a real number value in the interval [0, 1], denoted by $Y(t)$

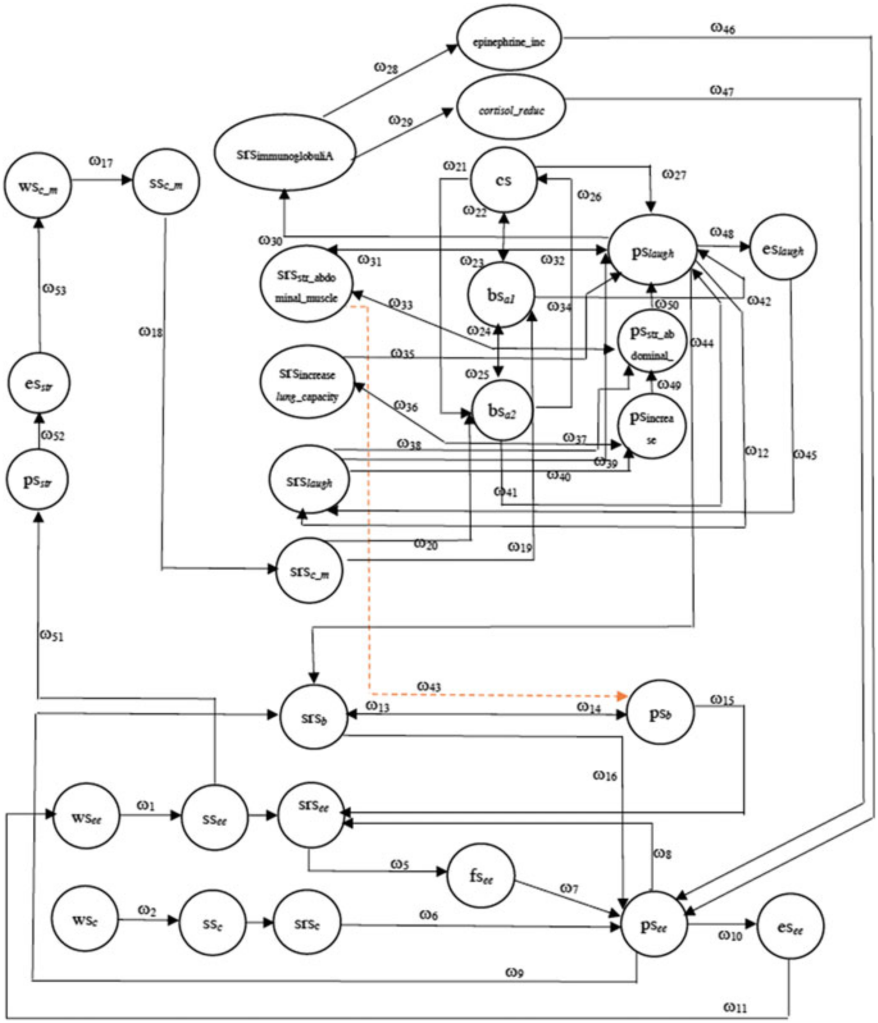

Fig. 1 Conceptual representation of the adaptive temporal-causal network model

- at each time point t each state X connected to state Y has an impact on Y defined as $\mathbf{impact}_{X,Y}(t) = \omega_{X,Y}\, X(t)$ where $\omega_{X,Y}$ is the weight of the connection from X to Y
- The *aggregated impact* of multiple states X_i on Y at t is determined using a *combination function* $\mathbf{c}_Y(..)$:

$$\begin{aligned}\mathbf{aggimpact}_Y(t) &= \mathbf{c}_Y\left(\mathbf{impact}_{X1,Y}(t), \ldots, \mathbf{impact}_{X_k,Y}(t)\right)\\ &= \mathbf{c}_Y\left(\omega_{X1,Y} X_1(t), \ldots, \omega_{X_k,Y} X_k(t)\right)\end{aligned}$$

Table 1 Explanation of the states in the model

X_1	ws_{ee}	World (body) state of extreme emotion *ee*	X_{15}	ss_{laugh}	Sensor state of laughing
X_2	ss_{ee}	Sensor state of body state for extreme emotion *ee*	X_{16}	$\mathrm{ss}_{increase\_lung\_capacity}$	Sensor state of increasing the lung capacity
X_3	ws_c	World state for stress-inducing context *c*	X_{17}	$\mathrm{ss}_{str\_abdominal\_muscle}$	Sensor state of stretching of abdominal muscle
X_4	ss_c	Sensor state for *c* (perceiving *c*)	X_{18}	$\mathrm{srs}_{immunoglobulia\ A}$	Sensory representation of immunoglobulin A
X_5	srs_{ee}	Sensory representation state of body state for extreme emotion *ee*	X_{19}	Epinephrine_inc	Hormone increasing
X_6	srs_c	Sensory representation state of context *c*	X_{20}	Cortisol_reduc	Hormone reduction
X_7	fs_{ee}	Feeling state for extreme emotion *ee*	X_{21}	cs	Control state
X_8	ps_{ee}	Preparation state for response of extreme emotion *ee*	X_{22}	bs_{a1}	First belief
X_9	es_{ee}	Execution state (bodily expression) for response of extreme emotion *ee*	X_{23}	bs_{a2}	Second belief
X_{10}	srs_b	Sensory representation of body state *b*	X_{24}	ps_{laugh}	Preparation state for laughing
X_{11}	ps_b	Preparation state of body state *b*	X_{25}	$\mathrm{ps}_{str\_abdominal}$	Preparation state for abdominal
X_{12}	ws_{c_m}	World state of comedy movie	X_{26}	$\mathrm{ps}_{increase}$	Preparation state for increasing lung capacity
X_{13}	ss_{c_m}	Sensor state of comedy movie	X_{27}	es_{laugh}	Execution state of laughing
X_{14}	srs_{c_m}	Sensory representation state of comedy movie	X_{28}	ps_{str}	Preparation state of starting humor movie
X_{29}	es_{str}	Execution state of starting humor movie			

Table 2 States and their relations to domain literature

States	Principles	Quotation, References
srs_{ee}	Sensory representation of the body state for the extreme emotion	'*The dACC was activated during the observe condition. The dACC is associated with attention and the ability to accurately detect emotional signals.*' [16], p. 12
ws_{c_m}	World state of comedy movie	'*Humor can refer to a stimulus such as a comedy film, a mental process such as perception, or a response such as laughter and exhilaration*' [29], p. 2
ss_{c_m}	Sensor state of comedy movie	'*Humor can refer to a mental process such as perception, or a response such as laughter and exhilaration.*' [29], p. 4
srs_{laugh}	Sensory representation state of laughing	'*Humor and laughter are typically associated with a pleasant emotional feeling.*' [23], p. 610
$\text{srs}_{\text{increase } lung\text{\_capacity}}$	Sensory representation of increasing lung capacity	'*Humor has been shown to increase lung capacity, strengthen abdominal muscles, and increase immunoglobulin A, which is one of the major antibodies produced by the immune system.*' [12, 34, 29]
$\text{srs}_{\text{str\_abdominal\_muscle}}$	Sensory representation of strengthening of abdominal muscle	'*Humor has been shown to increase lung capacity, strengthen abdominal muscles, and increase immunoglobulin A, which is one of the major antibodies produced by the immune system.*' [12, 34, 29], p. 2

(continued)

Table 2 (continued)

bs_{a1} bs_{a2}	Two belief states for two incongruent interpretations as a basis for getting humor from the comedy movie	‘*Cognitive theories typically analyze the structural properties of humorous stimuli or the way they are processed; sometimes these two levels are also mixed up. Perhaps beginning with Aristotle, incongruity was considered to be a necessary condition for humor. From this perspective, humor involves the bringing together of two normally disparate ideas, concepts, or situations in a surprising or unexpected manner.*’ [24], pp. 24–25
cs	Control state for resolving the ingruency of the two beliefs	‘*Only possible incongruities can be resolved completely while for an impossible incongruity only a partial resolution is possible, and a residue of incongruity is left. The definitions of incongruity (“… a conflict between what is expected and what actually occurs in the joke”)*’ [24], pp. 24–25
$srs_{immunoglobuliA}$	Sensory representation of immunoglobulin A	‘*Humor has been shown to increase lung capacity, strengthen abdominal muscles, and increase immunoglobulin A, which is one of the major antibodies produced by the immune system.*’ [12, 34, 29], p. 2
$es_{laughter}$	Execution state of laughing	‘*Laughter is the most common behavioral expression of a humorous experience.*’ [3, 29], p. 2
epinephrine_inc	Hormone	‘*Humor causes reductions in cortisol, growth hormones, epinephrine.*’ [1], p. 2
cortisol_reduc	Hormone	‘*Humor causes reductions in cortisol, growth hormones, epinephrine.*’ [1], p. 3

where X_i are the states with connections to state Y

- The effect of $\mathbf{aggimpact}_Y(t)$ on Y is exerted over time gradually, depending on speed factor η_Y:

$$Y(t+\Delta t) = Y(t) + \eta_Y\left[\mathbf{c}_Y\left(\mathbf{aggimpact}_Y(t)\right) - Y(t)\right]\Delta \mathrm{t}$$
$$\text{or}\qquad \mathbf{d}Y(t)/\mathbf{d}t = \eta_Y\left[\mathbf{aggimpactY(t)} - Y(t)\right]$$

- Thus, the following *difference* and *differential equation* for Y are obtained:

$$Y(t+\Delta t) = Y(t) + \eta_Y\left[\mathbf{c}_Y\left(\omega_{X1,Y}X_1(t), \ldots, \omega_{X_k,Y}X_k(t)\right) - Y(t)\right]\Delta t$$
$$\mathbf{d}Y(t)/\mathbf{d}t = \eta_Y\left[\mathbf{c}_Y\left(\omega_{X1,Y}X_1(t), \ldots, \omega_{X_k,Y}X_k(t)\right) - Y(t)\right]$$

For states the following combination functions $\mathbf{c}_Y(\ldots)$ were used, the identity function **id**(.) for states with impact from only one other state, and for states with multiple impacts the scaled sum function $\mathbf{ssum}_\lambda(\ldots)$ with scaling factor λ, or the advanced logistic sum function $\mathbf{alogistic}_{\sigma,\tau}(\ldots)$ with steepness σ and threshold τ.

$$\mathbf{id}(V) = V$$
$$\mathbf{ssum}_\lambda(V_1, \ldots, V_k) = (V_1, \ldots, V_k)/\lambda$$
$$\mathbf{alogistic}_{\sigma,\tau}(V_1, \ldots, V_k) = \left[\left(1/\left(1+\mathrm{e}^{-\sigma(V_1+\cdots+V_k-\tau)}\right)\right) - 1/\left(1+\mathrm{e}^{\sigma\tau}\right)\right]\left(1+\mathrm{e}^{-\sigma\tau}\right)$$

The Hebbian Learning considered here makes that the strength ω of an adaptive connection between states X_1 and X_2 is adjusted using the following Hebbian Learning rule, taking into account a maximal connection strength 1, a learning rate $\eta > 0$ and a persistence factor $\mu \geq 0$, and activation levels $X_1(t)$ and $X_2(t)$ (between 0 and 1) of the two states involved. The first expression is in differential equation format, the second one in difference equation format:

$$\mathrm{d}\omega(t)/\mathrm{d}t = \eta[\mathrm{X}_1(\mathrm{t})\mathrm{X}_2(\mathrm{t})\,(1-\omega(t)) - (1-\mu)\omega(t)]$$
$$\omega(t+\Delta t) = \omega(t) + \eta[X_1(t)\mathrm{X}_2(t)(1-\omega(t)) - (1-\mu)\omega(t)]\Delta t$$

4 Example Simulation

An example simulation of this process is shown in Figs. 2 and 3. Table 3 shows the connection weights used, where the values for the Hebbian learning connection is the initial value as this weight is adapted over time. The time step was $\Delta t = 1$. The scaling factors λ for the states with more than one incoming connection are also

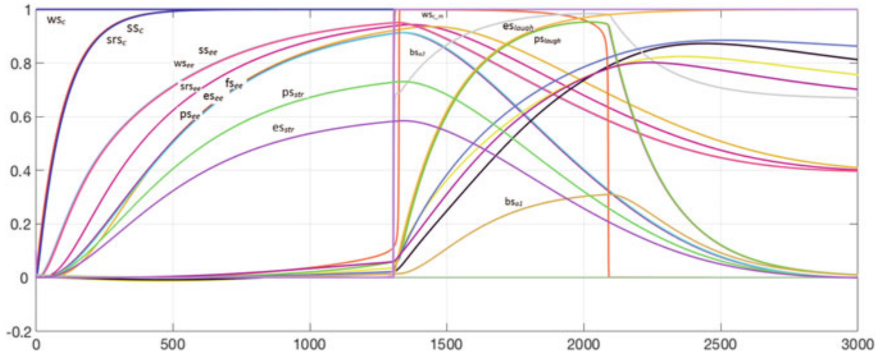

Fig. 2 Simulation results of the humor therapy

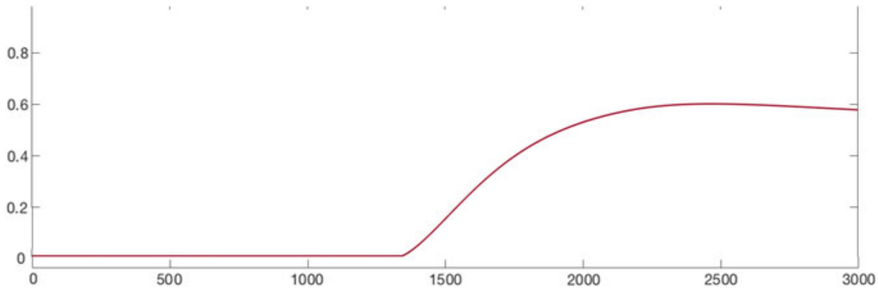

Fig. 3 Simulation results of adaptivity of humor therapy ($X_{17} - X_{11}$)

depicted in Table 3. In the scenario, the comedy movie is used as a basis for the humor therapy to decrease the level of the extreme emotion of the stressed individual.

The comedy movie gets a role from time around 1300 and finishes around 2200. After giving some time to the stressed individual to watch and sense the humor in the movie, the preparation and sensory representation of emotion starts to have a role and after internally being emotional she starts laughing from time around 1400 as an as-if loop from preparation state of watching movie and starts laughing (X_{15} and X_{16} and X_{17} as sensory representation states of laughing, ss_{laugh}, $\text{ss}_{increase\_lung\_capacity}$, $\text{ss}_{str\_abdominal\_muscle}$). The reduction of the stress level continues until the time around 3000 to become in the equilibrium level from 0.9 to just 0.4 (low-level of stress).

The results for adaptivity of the connection between sensory representation of stretching the abdominal muscle and the preparation state of a relaxed body state b has been shown in Fig. 3. As can been seen in Fig. 3 the adaptivity improves the effect of the Humor therapy and make it stable after finishing the therapy at time around 3000.

Table 3 Connection weights for the example simulation

Connection weight	ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8
Value	1	1	1	1	1	1	1	1
Connection weight	ω_9	ω_{10}	ω_{11}	ω_{12}	ω_{13}	ω_{14}	ω_{15}	ω_{16}
Value	−0.1	1	1	1	1	1	−1	−0.01
Connection weight	ω_{17}	ω_{18}	ω_{19}	ω_{20}	ω_{21}	ω_{22}	ω_{23}	ω_{24}
Value	1	1	1	1	1	1	1	−1
Connection weight	ω_{25}	ω_{26}	ω_{27}	ω_{28}	ω_{29}	ω_{30}	ω_{31}	ω_{32}
Value	−1	1	1	1	1	1	1	1
Connection weight	ω_{33}	ω_{34}	ω_{35}	ω_{36}	ω_{37}	ω_{38}	ω_{39}	ω_{40}
Value	1	1	1	1	1	1	1	1
Connection weight	ω_{41}	ω_{42}	ω_{43}	ω_{44}	ω_{45}	ω_{46}	ω_{47}	ω_{48}
Value	1	1	0.2	1	1	−0.1	−0.1	−0.9
Connection weight	ω_{49}	ω_{50}	ω_{51}	ω_{52}	ω_{53}			
Value	1	1	1	1	1			

State	X_5	X_8	X_{11}	X_{15}	X_{16}	X_{17}	X_{22}	X_{23}	X_{25}	X_{26}
λ_ι	2	2	1.55	3	1	2	2	2	3	2

5 Conclusion

In this paper an adaptive cognitive temporal-causal network model of a mindfulness therapy based on humor to decrease the level of stress of individual with extreme stress was presented. Due to Hebbian learning the model is adaptive by which the influence becomes stronger over time. A variety of simulations were executed one of which was presented in the paper. Findings from Neuroscience and psychology were taken into account in the design of the adaptive cognitive model. This literature reports experiments and measurements of humor therapy for emotion-induced conditions as addressed from a computational perspective in the current paper.

This model can be used as the basis of a virtual agent model to get insight in such processes and to consider certain support or treatment of individuals and prevent some stress-related disorders that otherwise might develop.

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